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Adding Physical Properties to 3D Models in Augmented Reality for Realistic Interactions Experiments

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Abstract

Augmented Reality is the combination of virtual objects (created by computer i.e. video, texts or 3D computer models) overlay on top of real world image. Applications of Augmented Reality can be ranged from advertising, edutainment, education, engineering, medicine to industrial manufacturing. In basic applications, like in advertisement or games, users only see the actions or interact with part of the screen designed for initiate some actions. In order to make users have realistic experiences, the interaction amongst virtual objects in Augmented Reality must be restricted to the law of Physics. Virtual objects can have their own dimensions, volumes or weights. When interaction between virtual objects occurred, the collision for example, they should not penetrate each other. The objects will react to each other by the law of Physics. With this concept, all kinds of experiments can be tested or practiced without spending a lot of fortunes with the real setup ranging from simple science experiment, medical training or even assembly process of equipment. In this research, Unity 3D game engine is used on Vuforia platform. Unity is a fully integrated development engine for creating games and other interactive 3D content and Vuforia platform make it possible to write a single native application that runs on almost all smartphones and tablets. To test the concept, 8 pieces of virtual 3D puzzle modules were created using 8 markers. Each virtual module was assigned with physical properties such dimensions, shapes and positions. When assemble the puzzle, each piece of the marker must be able to move around so that the virtual modules can fit to each other. By lifting and rotating the markers, the virtual module will snap with the other proper virtual part, forming virtual 3D puzzle. The virtual module will not penetrate each other because they have their own territory due to their dimensions. With this experiment, users will have a realistic feeling on assembling the virtual model. The concept can be implemented for experiments that are dangerous or expensive to setup. Experiments related to interaction between objects such as physics and chemistry experiments, engineering and medical training are the main targets for using this kind of technology.

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Keywords: Augmented Reality, Physical Properties, Realistic Interaction

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1. Introduction

Augmented reality (AR), by definitions, is a live view of a real-world environment whose elements are superimposed by computer-generated objects such as video, texts or 3D computer models. AR technology can be divides into 2 categories i.e. marker-based and markerless AR. For marker-based AR, upon their applications can be grouped into 2 types: image-based and location-based AR. Image-based AR needs specific labels to register the position of 3D objects on the real world image. In contrast, location-based AR uses position data such as data from GPS to identify the location. Applications using location-based AR, is ranging from presenting information based on the user's position in the real world to location-aware social networks with custom proximity notification. For realistic interaction experiment such as simulation, assembly training or educational experiments, image-based AR is preferred. Working with virtual objects in augmented reality, usually did not have realistic feeling like working with the real experiment, because the virtual model lacks of physical properties. By adding physics like volume, shape or density, the virtual experiment will be just like the real experiment. In this research, we would like to explore the possibility of using AR in assembly process that will provide a feeling likes working in the real environment, not virtual. For this purpose, the assembly of virtual 3D puzzle cube was set up to test the concept. Assembly process is important for manufacturing and virtual testing of the process will save both time and money. AR is perfect for this process due to the fact that user can experience 3D virtual experiment while still have real interaction with the parts (markers).

2. Related work

Research on augmented reality has been done for more than a decade. Only in the past few years, due to the advancement of the technology especially in hardware like smartphones and tablet, make it possible for real applications. Applications like navigation, edutainment, audiovisual aids, museums, medical, industry and advertising are among the most popular applications [1, 2, 3]. For some applications in the area of medical and engineering that needs realistic interactions between virtual objects or between user and virtual objects, there still need more research. In the field of manufacturing, augmented reality has been used for supporting assembly process for many years. Almost all of the research in the past deals with how to use augmented reality to train or guide the technicians to assemble the equipment or products. For example, Stark[4] used Augmented Reality for teaching the assembly of a car power generator in a serious game. Yue [6] study the use of augmented reality to guide assembly and disassembly of the jet engine. In this case text instruction, video clip and virtual demonstration were overlay on top of real environment. Park[6] use augmented reality to support cockpit module assembly system and confirmed that AR system can save cost and time in testing the real manufacturing process using prototype. Until recently, research on using AR in assembly process shift into the area of virtual models interaction which made assembly process feel more realistic. Lee H.K. et al.[7] study how virtual object can be deformed in augmented environment using physics based deformation. Research on key technique in AR-based assembly system such as occlusion handling, collision detection and human-computer interaction has been done by Zhu et al. [8].

3. Experimental Setup (System Setup)

To demonstrate how realistic interactions between virtual objects can be done using augmented reality concept, virtual 3D puzzle assembly experiment was set up. Unity 3D game engine is used on Qualcomm's Vuforia augmented reality platform. Unity is a fully integrated development engine for creating games and other interactive 3D content and Vuforia platform make it possible to write a single native application that runs on smart phones and tablets. The “Nana's 3D puzzle cube” (as shown in Fig.1) which composed of eight pieces with same volume but different shapes [9] were used for the demonstration.

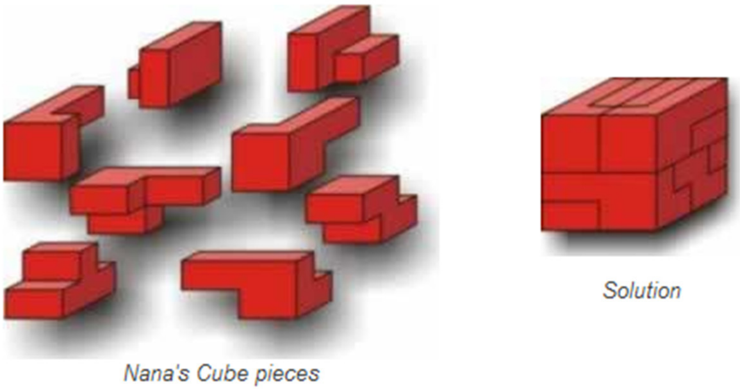

Fig. 1. Nana 3D cube pieces and the complete assembled [9].

The reason for using Nana 3D puzzle cube is that, each virtual pieces of the cube have the same volume and also same weight (when assigned to be made of by the same material or have the same density). When testing the physical interaction, such as collision, on virtual models the effect will be seen easily. In this experiment, we have created 8 markers represent 8 pieces of Nana 3D puzzle cube. The markers and their virtual puzzle modules are shown in Figure 2.

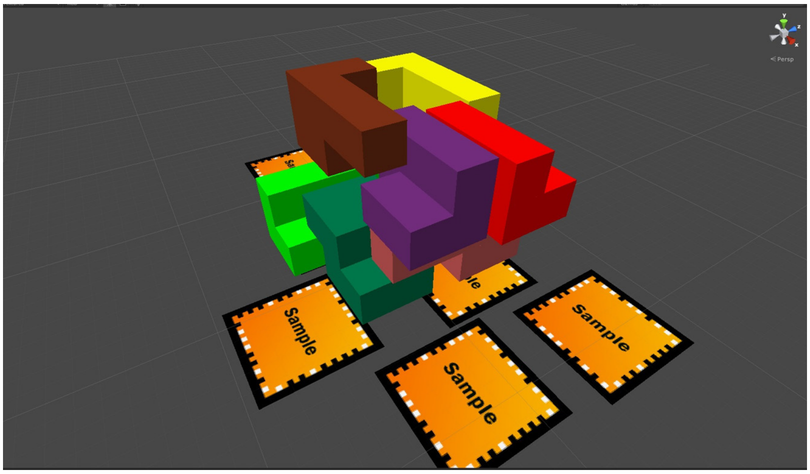

Fig. 2. Markers and their virtual representation modules

Physical properties like shape and weight were added to each virtual module of the puzzle, so that assemble of the modules feel realistic. To assemble the cube, the first marker is put in front of the camera and the virtual module of the part will appear as in Figure 3. Each of the virtual modules is formed by adding small cubes together (as shown in Figure 3). The small cube can be assigned to have some physical properties like “collision detection” in which we can use for calculation when interaction between virtual modules occurred. The virtual module also have the vector representation of 3 axis (x,y,z), which can be used for calculation as well.

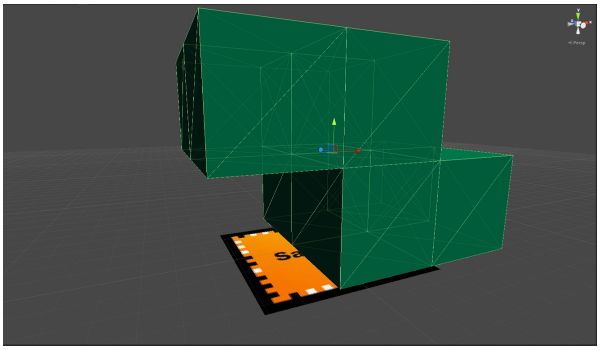

Fig. 3. Virtual modules of the part

By moving and rotating the marker that represent the virtual modules, the vision of the module will move and rotate just like moving the real module. Since the experiment setup using virtual parts of Nana 3D puzzle cube with physics, they behave just like putting the pieces of 3D puzzle together by using only one hand. By moving one marker close to the other, the virtual module will move closer to the other module and part of it may touch the other module. The module that was touched will move due to the force applied to it (as in Fig. 4) even though the marker did not move. The modules will separate from each other and it will take a lot of time to assemble them.

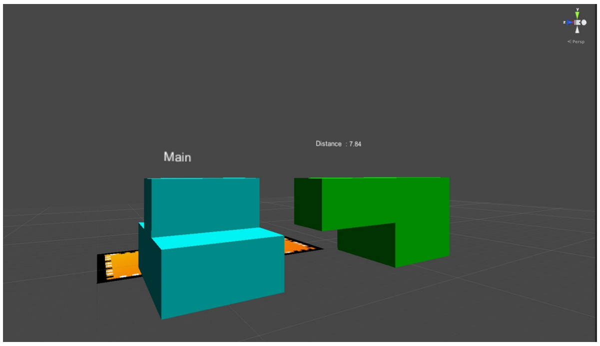

Figure 4 Interaction between virtual modules of the 3D puzzle cube

To solve this problem, we have setup one more virtual block with weigh 4 times the puzzle module to block the module from moving, just like using another hand to grab the piece (see Figure 5). With this concept, 3D virtual cube will be easier to assemble under augmented reality environment as seen in Figure 6).

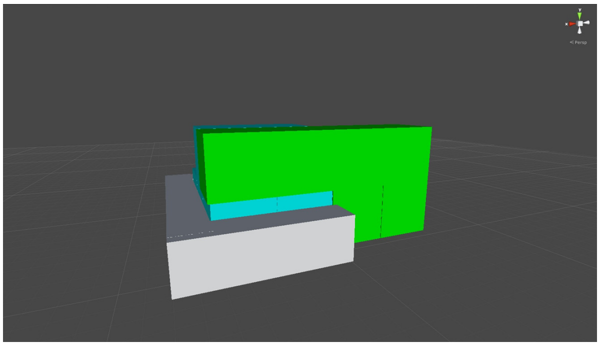

Fig. 5. Assemble two virtual modules by having virtual block to keep module from moving

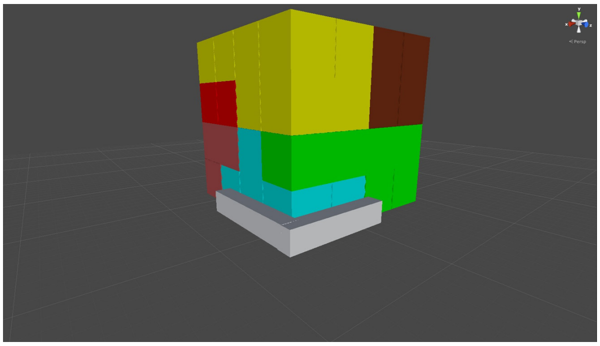

Fig. 6. Finished assemble 3D virtual Nana puzzle cube

To make all the modules snap together like when we assemble the puzzle in real life, calculations on distance and matching procedure were made. Figure 7 demonstrate the technique that was used to check the matching of 2 modules whether it can be attached together to form a new module or not.

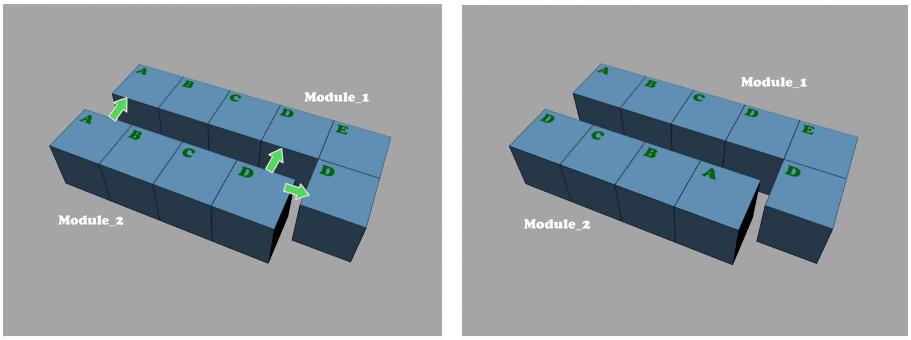

Fig. 7. Matching algorithm a) Matching b) Non-matching

From the figure, if we define that when every small cubes on module 1 are exactly match every cubes on module 2 then these two modules are snapped together (Figure 7 a). But if module2 was flipped, even it looks the same as in Figure 7a but each small cube in module 1 did not match small cube in module 2, then it will not snapped together (Figure 7 b). It is not necessary to define all cubes, only few cubes are good enough for matching procedure. Matching procedure can be defined by many algorithms but in this case, collision detection assigned to each cube is used.

4. Conclusions and Discussion

From the experiment, assembly of 3D puzzle cubes can be done with natural feeling using Augmented Reality. To make module assembly more practical, we have to find the way to grab the module so it will not move when collision with other module occurred. In this experiment we use the L-shaped virtual heavy solid block to stop the module but there may be other way to do it. This virtual assembly experiment using AR is just an example that can be modified for many applications such as in education, industry, entertainment and etc.

Acknowledgements

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